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AN UNUSUAL OCCURRENCE OF DINOFLAGELLATA ON THE CALIFORNIA COAST.

HARRY BEAL TORREY.

DISCOLORATIONS of the sea due to the presence of minute organisms, and often many miles in extent, have been seen in various parts of the world, along the shore and in the open sea. Deep-water sailors are familiar with such appearances, which they call "whale food," or "brim." The cause of the color is not always the same organism, though perhaps most frequently some species of Dinoflagellata, in enormous numbers.

This phenomenon was observed at San Pedro, Cal., during the present summer, and, according to the testimony of old residents, for the first time in that region. Something of the sort is said to have been noticed in Tomales Bay, some five hundred miles farther northward, in the early seventies. These are, I believe, the only known instances of its occurrence on the California coast; so that its rarity alone seems to demand a recording of the few notes taken during this last appearance.

It was first noticed on July 7 as a red streak off the mouth of San Pedro Harbor. During the next few days it approached the shore, changing its shape and dividing into several patches, each many acres in extent. On the 16th it reached the shore, and was the cause of a most unusual display of phosphorescence, which reappeared many evenings in succession. The phosphorescent water was found to contain vast numbers of a peridinium which I have referred tentatively to the genus *Gonyaulax* (see description below), and which gave it its red color during the day. Under the microscope *Gonyaulax* responded with a flash of light to any marked disturbance of the water containing it. At this time *Noctiluca*, so abundant later on, was not noticed. Wherever the ocean waters were roughened the wavelets were crested with green-blue light. In the quiet waters of the harbor the fishes, pelagic worms, and crustaceans traced trails of fire.

On the 20th, four days after the red (characteristically a muddy vermilion) streak had reached the shore, a most sickening odor arose from the water along the beach. On the 21st it was almost unbearable. During the night, on a beach about four hundred feet long, a large number of animals were left by the tide. Among them were several hundred holothurians (*Trachostoma arenata*), several specimens of two species of sting ray (*Mylobatis californicus* and *Urolophus halleri*), two species of guitar fishes (*Rhinobatus productus*, 3 individuals; *Platyrrhinoidis triseriatus*, 3 individuals), two cestracions (*Gyropleurodus francisci*), two dogfishes (*Galeus californicus*), a red perch, a large number of smelts, and several octopi. The fishes and octopi were dead, but many of the *Trachostoma* lived for several days. Many *Pinnixa faba* had crawled out of the cloacæ of the holothurians, on which they are normally parasitic.

On the 22d more *Trachostoma* were left on the beach. Some days later the odor had almost disappeared, but the water in the harbor and along the beaches was a brilliant vermilion. It was at this time that on two succeeding mornings a number of specimens of the blindfish (*Typhlogobius californicus*) were thrown up, both alive and dead. Then for two days came a number of *Tevila crassatelloidis*, many *Petrolisthes cinctipes* and *Cancer antennarius*. Finally, great numbers of *Hippa analoga* were thrown up, most of them alive but apparently debilitated and unable to dig as is their habit. They were mostly of large size.

This wholesale destruction was entirely unprecedented for the summer. The height of the tide and breakers were but subordinate causes at best; for, although the holothurians and selachians appeared after a higher tide and stronger sea than usual, as many of the former came up on a beach protected by a breakwater as on the beach shown in the photograph (Fig. 1). And as the tide fell from day to day, the animals did not cease to appear. The *Typhlogobius* appeared when the tide was moderate, with practically no sea running. This is interesting, not only because *Typhlogobius* usually lives, undisturbed by breakers, in holes and crannies among the rocks, which must

have been in this instance some distance from the beach, but also because it has never before been reported from San Pedro. The *Gonyaulax* served here as a means of discovery.

The above facts have been enumerated because they exhibit in a striking way a natural cause in process of eliminating the unfit of several and diverse species, which are resisting with various degrees of persistence and success. Whether this elimination is promiscuous, or correlated with variation from the type



FIG. 1. — Beach covered with dead animals, mainly holothurians with several selachians in the foreground ; a result of the appearance of *Gonyaulax*.

of the species, is a question for whose solution material has been collected by Dr. F. W. Bancroft of this laboratory.

The "red water" occurred for two hundred miles at least along the coast, from the region of Santa Barbara to San Diego, and extended several miles to sea. It was still present around San Pedro on September 1. Wherever it was seen the fishermen reported a scarcity of food fishes. The small harbor fishes seemed to be unaffected by it, and the tiny invertebrates of the plankton were abundant in it. *Noctiluca* appeared in great numbers toward the end of July, and devoured *Gonyaulax* with

avidity. There were more copepods in the red streaks than in the intervening bluer water. I was not able to see any *Gonyaulax* in them, however.

Gonyaulax undoubtedly produced its harmful effects by dying in enormous numbers, the putrefactive changes thus occasioned polluting the water and giving rise to the stench already mentioned. It died most rapidly along the water's edge, thus affecting the littoral animals especially.

When placed under the microscope for examination in a drop of water, many *Gonyaulax* soon became quiescent, and the protoplasm drew away from the cuirass, forming a spherical cyst, which was often discharged by a rupture of the cuirass along any sutural line. Others died outright and disintegrated, leaving only the transparent, colorless cuirass. This tendency to die readily was noted long ago by Darwin for a species of dinoflagellate found in swarms off the western coast of South America.

With this enormously abundant species other species of Dinoflagellata were found: *Ceratium furca*, *C. fusus*, *C. michaelis*, *Peridinium divergens*, *Prorocentrum micans*, *Polykrikos* *sp.*, *Dinophysis* *sp.*, *Noctiluca* *sp.*, and certain swarmspores resembling those of *Peridinium ovatum*. The most abundant of these was *Noctiluca*, toward the end of July, but it did not begin to approach *Gonyaulax* in numbers. Where there was one *Noctiluca* there were hundreds, if not thousands, of the other form. The latter was present in the tow as early as June 17, in company with, and about as abundant as, the above-named species. All of these species increased during July, but *Gonyaulax* outstripped the others remarkably. The cause of this increase of one species over these closely related and associated species is not clear. I did not see a single case of fission, but the individuals varied so greatly in size as to suggest rapid reproduction, probably by encystment and spore formation, though no spores excepting the large *Peridinium* (?) swarmspores were seen. *Noctiluca* was sporulating at this time. It is possible that the immense patches of *Gonyaulax* were brought in by currents from deep water. Nothing, however, was seen of them throughout the season around Santa Catalina Island,

some twenty miles to sea. And if this were so, the cause of the rapid reproduction would still remain obscure.

The boundaries of the red streaks were quite sharply marked, although the water between streaks often contained *Gonyaulax* in abundance. Temperatures and determinations of salinity were taken at the surface and at the bottom of both red streaks and water entirely free of *Gonyaulax*. The readings averaged the same in all cases for the same depths. Soundings with a rather crude water bucket indicated that *Gonyaulax* was present approximately in as great abundance at the bottom at the depth of six fathoms as at the surface.

The key to the problem lies, I believe, in the chemical constitution of the water, since, aside from a sensitiveness to chemical

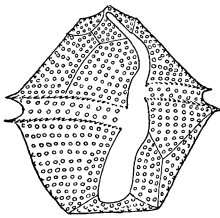


FIG. 2.

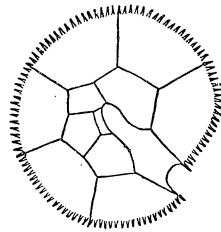


FIG. 3.

FIG. 2. — *Gonyaulax*, showing both longitudinal and transverse furrows.

FIG. 3. — *Gonyaulax* from upper pole, showing arrangement of anterior plates.

stimuli which it possesses in common with all living things, *Gonyaulax* is holophytic, if its color is a safe criterion. Zumstein has recently shown that the chlorophyll-bearing *Euglena* may lose its color under appropriate conditions and change its method of feeding in consequence to the saprophytic type. The *C. michaëlis* and *Polykrikos* *sp.*, as well as the *Peridium* (?) swarmspore, found with *Gonyaulax*, were colorless. Not only, then, within the limits of one family of protophytes do two methods of nutrition exist, but in a single species, and possibly in a single life cycle. But the question of the source of the food of marine organisms is too vast a subject to be attacked with the scanty materials at hand. Whether *Gonyaulax* is nourished by inorganic or organic solutions, and whether a variation in food supply is the explanation for its unusual abundance, are problems to be solved by future experiment.

I have called the dinoflagellate with which these notes are chiefly concerned *Gonyaulax*, because in the first place it approaches that genus very closely, and in the second place such a small amount of the literature of the group is accessible to me that I do not feel warranted in erecting a new genus for it. It differs from *Gonyaulax* as described in Engler and Prantl's *Die natürliche Pflanzenfamilien* only in that in the anterior moiety of the cuirass there are six intermediate plates instead of five, and four end plates instead of three.¹ It may be described as follows (Figs. 2, 3):

Body divided by the equatorial furrow into two subequal halves, each of which is a low cone, the posterior one truncated. Anterior cone formed by six large intermediate plates meeting four much smaller unequal end plates in an angle somewhat less than one hundred and eighty degrees. Posterior cone of five large intermediate and one large end plate, with a narrow accessory plate next the longitudinal furrow. Equatorial furrow slightly oblique, deep, with toothed edges. Longitudinal furrow broader posteriorly than anteriorly, extending from the edge of the posterior end plate to the apex of anterior cone. All plates regularly bossed. Sutural lines raised into high, narrow ridges.

The equatorial flagellum alone is active in ordinary swimming, producing a rapid rotary and forward movement. The other, which trails behind during such progress, is responsible for the spasmodic jerkings occasionally seen.

The size of the cuirass varies from $25\ \mu$ in diameter by $29\ \mu$ in length, to $53\ \mu$ by $56\ \mu$. Cysts average $24\ \mu$ in diameter. They are almost spherical, with granular contents of a brown-green color. Cuirass itself colorless.

ZÖOLOGICAL LABORATORY, UNIVERSITY OF CALIFORNIA,
September, 1901.

¹ Since the manuscript was sent to press I have found that Bütschli (Bronn's Klassen und Ordnungen) has noted a similar discrepancy between the original description of *Gonyaulax* and his own observations, which leads me to suspect that the genus was wrongly defined by its author.